THE MISSISSIPPI RIVER PROBLEM.

BY LEWIS M. HAUPT.

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In the economic development of the Federal Domain, the fostering care of a paternal Government has been liberally extended, by Congress, to the granting of homesteads to actual settlers ; to the reclamation of arid lands by irrigation ; to the donation of swamp lands to States for educational purposes ; to the subsidizing of the overland railroads by extensive land grants and to the setting aside of large tracts for the Indian tribes for ranges, and in many other ways has it stimulated the enormous traffic and wealth of the country.

Still there are waste places which may be made to blossom for a relatively small sum of money, but which cannot be rendered habitable at the expense of the individual settler, and undeveloped communities are likewise unable to reclaim extensive tracts from a foe which may attack them from all sides. General defensive works are of paramount importance to protect property and encourage the settlement of the richest land in the world, and it is manifest that the burden of this reclamation should be borne by those who derive the benefits from the increased yield, namely, the consumers as well as the producers.

But there are great and honest differences of opinion as to the methods which should be followed to secure these results.

The local owners and settlers firmly adhere to the reclamation of their land by levees to exclude the water, regardless of the ultimate consequences from confining the floods to a greatly congested bed They fail to realize that if the fertilizing silt is excluded from the plains it must be dropped in the bed of the river and cause it to rise, and impair navigation as well as increase the menace to property.

The great necessity for reclamation and protection works seems to have beclouded the issue, and undue stress is laid upon that particular phase of the problem, whereas the intention of the Government, as originally proposed, was to open the channel and control the stream for navigation.

These two purposes are so distinct in character as to claim separate jurisdiction under different departments of the Government,

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and are both mutually dependent upon Government appropriations for a successful issue. Works built to reclaim land are not generally well adapted to the creation and maintenance of channels, as will appear from the experience cited later in this paper, and hence the demand for a system of levees which shall at the same time protect the land and create a navigable channel is incongruous, and will also be found to be opposed to existing statutes.

Much greater progress in both directions, it is believed, can be made if the two issues are divorced and separate plans be devised for each on its merits.

In this connection it will be found suggestive to note some of the divergent views expressed by the speakers at the Levee Convention, held at New Orleans, October 27–28, 1903.

It was said, but not by engineers, that "protection can come only from a national system of massive dikes . . . . the system of reservoirs (is) utterly unfeasible and impossible." . . . . "Outlets are not only impracticable but harmful." A distinguished member of the Mississippi River Commission stated: "The progress of levee extension has been a repetition of the early history . . . . their upward extension has cut off more and more of the former overflow. . . . . The necessary result has been to raise the flood level higher, and so make it necessary to build the levees higher. . . . . The last flood has left behind it a record of mingled disaster and success."

On the other hand the Committee on Resolutions reported that the investigations made by the Commission "wholly disproves the notion, which still prevails to a considerable extent, that the immediate effect of levee construction is to cause the bed of the Mississippi river to rise. If this were true it would necessarily follow that the levees would need to be continuously strengthened and elevated, and thus all hope of protection would have to be abandoned." Thus the case is prejudged by its advocates.

But another close observer remarks: "You are not wise if you do not see that the drainage from this vast basin (the Missouri) will flow into your river faster than you can raise your banks, and the levee system will in time prove a failure. . . . . If you go on and complete your levee system as you desire to, in less than twenty years you will be clamoring for some system to get the silt from the water back upon your lands for the fertilization of your plantations."

Again it was urged that the confidence inspired by the levees had caused the value of property to advance "all over the alluvial valley, in some places 100 per cent., in some places 200 per cent., in some places 300 per cent"; but a distinguished Senator calls attention to the fact that Congress," under the Constitution, had no power to appropriate money to protect private property. I want to say to-day that every dollar that has ever been appropriated for levees on the Mississippi river has been on the theory that it would benefit navigation, and we never dared to put it on the ground, up to this day, that it would benefit private landowners, though we knew of course that it was incidental to it."

The success or failure of this improvement must, therefore, hinge upon the ability to prevent the elevation of the bed and its silting up by the larger amount of sediment confined to its channel and the relief of the excessive high stages by other expedients than levees, and it is to the consideration of this question that the following pages are directed.

A Method of Controlling Floods on Mississippi.

Prior to the Louisiana Purchase in 1803, the territory of the United States was limited to the area east of the Mississippi river and north of the Spanish possessions in Florida, giving no independent outlet for the products of the republic other than that across the Appalachian Mountains to the Atlantic Ocean.

By the purchase of the territory extending from the mouth of the river on the Gulf to Puget Sound on the Pacific, the United States came into peaceable possession of the most fertile and productive region within its borders and secured control of the navigation of the greatest river in length on the globe.

Up to the middle of the last century the population was comparatively sparse and the products limited, but after the restoration of peace and the opening of the country by roads and railroads, the development became so rapid as to require a systematic and comprehensive effort to regulate and control its avenues of interstate and foreign commerce under the control of the general Government.

The frequent casualties to the palatial steamers traversing these western waters from snags, bars and shifting channels with insufficient depths finally led to the organization of the Mississippi River

Commission in 1869, for the purpose of permanently improving the stream from the head of the Passes to the headwaters.

The duties of the Commission as set forth in the law of June 28, 1879, read as follows:

"Section 4. It shall be the duty of said Commission to take into consideration and mature such plan or plans and estimates as will correct, permanently locate and deepen the channel and protect the banks of the Mississippi river; improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade and the postal service; and when so prepared and matured to submit to the Secretary of War a full and detailed report of their proceedings and actions, and of such plans with the estimates of the cost thereof, for the purposes aforesaid, to be by him transmitted to Congress; *provided*, that the Commission shall report in full upon the practicability, feasibility and probable cost of the various plans known as the jetty system, the levee system and the outlet system, as well as upon such others as they deem necessary."

This was the authority for the subsequent systematic improvement of the river, which has proven to be an impressive object lesson as to the greatness of the problem and the difficulties to be overcome.

After so many years of experience, with a large amount of reliable data at hand, and with the voluminous discussions, more or less acrimonious, between the advocates of various systems, it may be profitable to weigh dispassionately some of the evidence and note where we are trending.

This may be done best by quoting the language of the Commission itself in the Report of 1903, just published:

"Systematic work, which has for its object to permanently locate and deepen the channel, has not been practicable under existing conditions. In the limited extension and repair of bank protection and contraction work the Commission has, however, kept in mind that the permanent improvement of the river is contemplated by the organic act, and experiments are continually being made looking to the best use of available material and the development of appliances and methods which may be economically and effectively employed when Congress shall provide for such a systematic improvement."

From which it appears that the permanent and systematic plan

is still conditioned upon the results of experiments and further legislative action by Congress.

Prior to the organization of the Commission a Special Board of five United States Engineer officers was appointed July 8, 1878, to report a plan for the Improvement of Low-Water Navigation, and on the 25th of January following, the report was submitted, recommending the general plan of "contracting the channel to an approximate low-water width of 3500 feet by means of dikes of brush, etc., and where the bed of the river is found to be too hard to be worn away by the river currents, dredging, in addition to the reduction of width, to be resorted to."

In this report attention is directed to the fact that "there is an ample depth wherever the thread of the current follows a well-marked concave bank. Also wherever the low-water width does not exceed about 3500 feet," and, conversely, navigation is bad wherever there are straight reaches and the width exceeds this limit. Another element of serious importance is the great instability of the channel, which shifts through a breadth of several miles, due to the caving of the banks, which proceeds "at the rate of 200 to 300 feet a year in certain places, and these amounts are sometimes much exceeded."

As to the available depths at that date, the report states that "there are forty-three places between Cairo and the mouth of the Red river where low-water depths of less than ten feet and thirteen where depths of less than five feet may be found. . . . . There were fifty-two days on which the least depth of water between St. Louis and Cairo was less than six feet, and sixty-nine days when it was less than ten feet."

These considerations led the Board to conclude that "protection of caving banks will therefore be needed. . . . . To thoroughly regulate the river caving, even in those bends which have deep water below them, should be stopped. . . . . The protection of these caving banks can be effected by mattresses. Where the water is deep it will be very expensive." . . . . "That such a trial may thoroughly test the practicability and the cost of regulating the river and increasing its low-water depth, one of the worst places on the river should be selected."

Accordingly the Board recommended the appropriation of $600,000 for revetments on the Plum Point reach, one hundred and sixty miles below Cairo, which was granted and the test made.

Extensive revetments were also applied at Lake Providence and other points on the river, but the difficulty of holding them against the great pressure of the floods and their enormous expense have led to their abolition.

This Board of Engineers also reported on January 25, 1879, upon the effects of a permanent levee system throughout the length of the river below the mouth of the Ohio, not only upon the low-water navigation but also of the benefits it would confer in affording protection and giving needed facilities to shipping, commerce and navigation in the high stages of the river.

The Board found that "levees have no direct action except when the water is high. . . . . A glance at the sketches is sufficient to show that levees, even if they come into action every high-water stage instead of only every 'flood,' would have little or no influence on the low-water navigation. They would leave to the river its inordinately great width and area of shifting sands, and exert little or no influence on channel formation. This would be the fact even if they everywhere followed closely the natural banks. . . . . Closely adhering levees which in all high stages shall confine the water which now escapes into the swamps would, by an increased current action, accelerate the caving of the banks in the bends and enhance the instability of the bed, which now not only makes the work of navigation improvement so difficult, but is one of the most formidable foes to a permanent levee system. . . . . The great obstacle to the improvement of the low-water navigation and to maintaining a levee system is one and the same for both, viz., the instability of the river from the caving of its banks. . . . . We believe that the levee system, if undertaken, should be matured and developed in connection with the navigation improvement."

Hence it appears that this Board attached but little importance to the use of levees as an aid to the formation of a navigable channel, although recognizing their value in the reclamation of land.

It relied upon the regulation of the channel by dikes and revetments to correct the evils, but the past experience has destroyed this expectation and compelled a change of policy which it may be well to review as to its consequences.

After the greatest flood to that date, which occurred in 1882, the Commission reported that the controlling depths at low stages between Cairo and Plum Point reach were but five and one-half and six feet; that a large amount of the revetment had been lost, and

that to determine the effect of outlets surveys had been made during and after the large crevasses caused by that flood, from which it was concluded that the relief which might have been anticipated from the decrease of flow below the outlet was not realized, because the water thus released returned to the river lower down and obstructed the discharge at that point, making a water-dam.

It should not be concluded from this fact, however, that outlets are injurious, for it is not proposed to permit the excess of water immediately to flow back to the lower reaches, but to impound it for a considerable time in large reservoirs, thus changing entirely the conditions and removing the objections to the ordinary operation through natural crevasses, which are wholly different from the impounding reservoirs proposed by Mr. Seddon for the relief of the floods.

This Commission reiterates its statement "that for purposes of channel improvements merely, the limit of economy is reached with the confinement of the ordinary flood. The result of this qualification is that the building of levees to the height necessary to protect the alluvial basin from overflow, is not necessary as a part of the logical plan of river improvement." This policy was doubtless reflected in the legislation which followed, making it illegal to appropriate money for protection works unless they were found to be beneficial to navigation.

The Joint Resolution passed March 3, 1891, *re* Mississippi river levees, reads as follows :

"*Resolved, by the Senate and House of Representatives of the United States of America in Congress assembled,* That the sum of one million dollars is hereby appropriated, to be paid out of any money in the Treasury not otherwise appropriated, for the improvement of the Mississippi river from the head of the Passes to the mouth of the Ohio river, which sum shall be immediately available and shall be expended under the discretion of the Secretary of War, in accordance with the plans, specifications and recommendations of the Mississippi River Commission ; *Provided,* That no portion of this appropriation shall be expended to repair or build levees for the purpose of reclaiming lands or preventing injury to lands or private property by overflows ; *Provided, however,* That the Commission is authorized to repair and build levees, if in their judgment it should be done, as part of the plans to afford ease and safety to the navigation and commerce of the river and to deepen

the channel; *Provided, further,* That the office, clerical and traveling expenses and salaries of the Mississippi River Commission may be paid from this appropriation.

"Approved, March 3, 1891."

From this law it appears that, unless the levees are beneficial to the navigation, there is no warrant for the application of Government funds to their construction and maintenance; hence it happens that there is great difference of opinion as to the results produced by them, and it is strenuously urged, doubtless in good faith, by those on whom the burden of levee construction falls so heavily, that the river bed is *not* rising, nor is the channel shoaling, while on the contrary the actual and carefully conducted surveys made by the Commission indicate an unmistakable reduction in the depth and area of the low-water channel, and an increase in the caving and instability of the banks with greater flood elevations than before, as will presently appear.

The logical inference from these data would seem to point conclusively to the necessity for a modification of the levee system and a resort to one which will relieve the floods, while at the same time it reduces their height and also maintains a more constant low-water stage, with greater depths for navigation. Under such a system the Government *would* be fully justified in making appropriations for maintaining low levees, supplemented by outlets and receiving basins for storage of the excess of flood waters.

This involves the removal of all bars or obstacles which retard discharge, beginning at the mouths and proceeding up stream; the readjustment of the alignment at the gorges and the construction of reservoirs in the swamps, especially of the St. Francis basin.

Before leaving the report of the Commission of 1883, it is desirable to state further that, under the views as above outlined, the estimate for the "levees on the Mississippi river at certain grades" aggregated $11,443,770; but it recommended the "closure of the gaps in the existing levees along the Yazoo and Tensas fronts, begun a year ago, as the most economical and shortest method of shutting off the escape of water into those great reservoirs, and securing so far the benefit of the entire discharge in the improvement of the channel. Beyond that the Commission is not prepared at this time to make any specific recommendation for construction of levees as a means of channel improvement, and reserves the subject for further consideration."

In closing the report the Commission calls attention to the peculiarly favorable conditions of the outlet section of the river in these words :

"In conclusion of this subject, the Commission considers it necessary to call the attention of Congress to peculiar conditions existing below Red river. This section of the river is in a state of much greater stability than is found in any other part of its course below the junction of the Missouri. At a short distance below Red river it becomes narrower and deeper. It has been leveed throughout for a great many years. No flood complications arise here, as above, from the return of overflow water which has escaped from the river at points higher up. This all reaches the sea through the numerous delta bayous on either side."

This reach, therefore, furnishes the best object lesson available as to the proper treatment of the river, and is a complete answer to the objections to the use of outlets, for the volume of discharge, when in flood, is only about one-half that of the river above the mouth of the Red, and yet the depths are more than ample, reaching in places to two hundred feet. The escaping waters do not return to the bed but are permanently withdrawn, and there are no such variation of channel widths as are to be found between the lines of levees as constructed in the higher reaches.

The President of the Commission, however, did not coincide with the majority on the question of levees and outlets, with reference to which he said :

"Considering . . . . the probability that the height of floods will increase in the future, it seems proper that in the plan for any general system of levees, if the principle of keeping out all floods, whatever their height, should be surrendered (a step of doubtful advisability), the plan should at least provide for holding a flood like that of 1882. A thorough study of the subject of levees has not yet been made; until then accurate estimates are impossible. . . . . Such as they are they make it impossible for me to concur in the estimate of $11,443,770 as the cost of a general system of levees from Commerce, Mo., to the Forts, adequate to preserve that country from destructive floods."

From the foregoing records it appears that the Commission, after a careful investigation covering about fourteen years, had little or no confidence in the ability to regulate the river by revetting the

banks, and no faith in high levees to improve the navigation at low stages.

Consideration of the problem continued and many of the most experienced engineers on the works participated in the discussion.

The local Levee Boards of the several States were obliged to continue their protection works, which were assuming greater proportions as the system was extended, and great pressure was brought to bear upon the general Government to aid in the work of defending the arable land from overflow, and thus confine the floods to the narrower channel between the artificial banks.

As a matter of record it is important to note the arguments advanced by the competent and conscientious men in charge of these works.

In November, 1892, the Chief Engineer of the Yazoo Levee Board stated that "the levee system, which is the one now in vogue, has been objected to on several grounds—that it was very costly, that it was very dangerous, and that it exposed the river to deterioration from the confinement of silt, causing the deposition of silt in the bed of the stream."

In reply to these objections he says that up to that time the cost would probably be covered by $35,000,000, and that to build the levees to a height now (1892) considered sufficient, namely, five feet above the highest recorded floods, would require some $20,000,000 more. He adds there is no difficulty in making levees that will secure against disaster. The flood of 1892 was one foot higher than ever before, but there was no break along the Yazoo front; and the third objection, as to elevation of bed, he repudiates as opposed to all testimony.

In his report on the flood of 1903, his successor, also an engineer of long experience on the river, states that the present flood reached a stage exactly three feet above that of 1897, and was prevented from reaching a higher point by the two large crevasses which occurred in the St. Francis basin levees two or three days before the culmination of the flood at Memphis. Correcting for this and the lower gauge reading at Cairo, the present rise might have reached an elevation of four feet above that of 1897. Below Burk's Landing, within the next few miles, are four unclosed crevasses that occurred in 1897, aggregating over a mile in width. There was a crevasse at Rescue Landing in 1897, which lowered the stage locally nearly one foot. He suggests that the grade line of 1897,

which was a little under five feet above the flood-plane of that year, should now be raised to five and a half feet. He also foresees the still greater dangers from increased floods, and suggests in places the construction of reserved and subsidiary lines of levees to cover the emergencies arising from the increased caving of the banks.

The report states: "With a considerable addition to the high-water elevation that may be expected in the near future, it may be assumed that the current force and the general difficulties of the situation will be further magnified."

With reference to the dangers from caving banks he reports:

"The situation here (near Rescue) has become still further complicated to a grave degree by the accelerated rate of caving of the river bank opposite the new levee, which threatens its destruction from that source in a comparatively few years. The greatest development is about the middle point of the new levee, where the bank has receded nearly five hundred feet since November, 1898, with less than seven hundred feet remaining to the levee. In order to retire this line to a more secure location it will be necessary to fall back into very low ground, which would still further magnify the difficulties to be encountered. In view of the foregoing facts the conclusion seems inevitable that the maintenance of the front line extension as a permanent feature of our levee system must be abandoned." . . . . "Any further effort to hold this levee end will be well-nigh hopeless of good results."

Again he says:

"The instability of the foundations of the Ward Lake line has been very much in evidence already. With an increase of five or six feet of water pressure this evil will be increased to an unknown but undoubtedly great extent, and will probably require a secondary line, in the nature of a sub-levee, throughout most of its length.

"From renewed activity in caving of the bank along the Burk front, it seems now probable that about one and one-half miles, and possibly more, of that levee will have to be renewed within the next few years." The instability of the bed is further shown at the head of Island 63, where the river is returning to the old channel on the Mississippi side. "This development threatens the stability of some three miles of levee above Burk's Landing that was heretofore considered reasonably secure."

"It has been forcibly demonstrated by this high water that one of the greatest problems of the future shall be to combat the dan-

gers arising from defective foundations of the levees; that is to say, from the permeable and treacherous character of the natural earth foundation, which permits the passage of large volumes of water beneath the levees. This water is forced up by hydrostatic pressure through every aperature or weak place in the crust above. The flow in many cases comes with great freedom, bringing up large quantities of sand and leaving a corresponding displacement of material under ground. . . . . This agency will increase in energy as the river goes to higher stages in the future and demands thorough and systematic treatment."

The estimates submitted to the State Board for work of primary importance aggregates $627,000, of which $441,000 is for new levees.

From this evidence it appears that there is some "difficulty in making the line secure against disaster," and that large breaches have actually occurred; also that there is an ever-present danger of failure in the most vital part of every structure, namely, the foundation, from the constantly increasing head due to the concentration of the waters, and that the increasing caving of the banks requires not only new lines but reserved levees, thus greatly adding to the cost.

The estimates previously submitted as being sufficient to complete the system have been several times exceeded, and it is now stated that to bring the levees up to a safe standard will require about forty per cent. more material than has been already put in place.

But there is no well-defined limit to the height or extent of the works, since the river is not controlled nor the erosion reduced.

A distinguished engineer, employed on the river for many years, states: "The uncertainty as to future flood volumes and the stages consequent upon a confined channel are so great, however, that the great devastation from crevasses, caused by the river overtopping the levees, will continue for many years to come. The banks will never be fully protected from caving, and the channel will always be very unstable and will shift more or less in position. . . . . The effect of the levees is to increase the height of the bars so long as the very unequal widths are uncorrected, for a confined river means higher flood stages, and the higher the stage the higher the bars are built up in the wide reaches. Therefore, the regulation of the width and the protection of the banks should precede the building

of the levees. But the popular demand for levees has reversed this order."

It would seem, therefore, that in consequence of the instability of the bed and banks with their superimposed levees and the increasing heights of the floods, the question of the ultimate cost is indeterminate but great.

In military practice it is found to be good tactics to disperse an enemy and attack him in detail, but the levee system appears to reverse this mode of procedure and concentrates the energy of the flood for a thousand miles, so that if there be a weak point in the ramparts it will assuredly discover and breach it.

The third point of contention has been discussed *pro* and *con*, but is of such importance that a few citations are deemed necessary to state its status. For example, it is said :

"The cross-section of the river will gradually rise, and has risen *where not leveed*. . . . . It is not claimed by the advocates of the levee and contraction system that there will be an appreciable or immediate lowering of the bed of the river. . . . . It will take many years. . . . . But that the raising of the bed to any measurable amount in centuries to come will take place is not admitted." The writer then cites the Po.

In other words, the levees have no appreciable effect on the elevation or the depression of the low-water, or even on the high-water, channel in any sensible period of time. If so, there is no justification for their construction as aids to navigation, and hence no warrant for the appropriation by the general Government.

The Po, which is so frequently cited as an illustration that the bed is not rising, appears to be much misunderstood.

One of our most distinguished United States Engineer officers is quoted as saying : "The river Po has long been leveed, and it is often stated that its bed has risen largely in consequence of levees. The following data will show how unfounded is the statement that the bed has risen by amounts that are of much importance." He then adduces the data in the form of gauge readings and adds : "The above gauge readings, which have been kept only since 1807, show that there has been no important rise of the river bed (since that could not rise without raising the low-water surface) in the past sixty-eight years."

This testimony, therefore, admits that the bed does rise but minimizes its amount, and falls into the error of assuming that the eleva-

tion of bed is reflected in that of the surface as recorded by the gauges. That the bed may rise and yet the gauge readings diminish, will be apparent when it is remembered that the width may be increased by caving and the area of the cross-section be increased even, with a resulting lower record on the gauges, as has happened in the Mississippi. Moreover, it is admitted that even in a state of nature or without levees the bed will gradually rise. It is, therefore, only a question of degree as to whether the rate of elevation is augmented or not by the levees.

To determine this mooted point as to the elevation of the Po, an American scientist made a personal inspection and reported his observations in 1896.[1] In his description he says, *inter alia :* "Sir Charles Lyell has been frequently quoted as stating, 'At Ferrara the surface of the water has become more elevated than the roofs of the houses.' . . . . My visit showed this danger to be less imminent than might be supposed. Its population has dwindled away from 100,000 to less than 30,000, while great stretches of land within its walls are now quite deserted. It is in a great plain only six and a half feet above the sea level. The roads across the plain are raised considerably above the general level, thus keeping them dry.

"In 1847, Lombardini showed by actual measurement that the mean height of the Po only here and there rose above the general level of the plain and was generally considerably below it, and that even during the great flood of 1830 the pavement in front of the Palace was scarcely ten feet below the level of the surface of the water in the river. Since that time, however, these conditions have altered in a marked manner, the more recent investigation of Zollikofer having shown that in the normal condition of the river the surface of the water in the neighborhood of Ferrara is somewhat over eight feet above the surrounding plains, while in flood the water in some places rises from sixteen to nearly twenty feet above the plain on either side.

"The dikes are estimated to be twenty-six feet high, and the crest is cut down somewhat to permit the road to pass through with easier grades, but the cut is closed with a brick wall arranged for stop-planks to exclude the higher floods. Though the danger is not so great as indicated by Lyell, yet the river in flood time hangs suspended, so to speak, over the surrounding plains, and the city of

[1] See *Science* of May 22, 1896.

Ferrara might be subjected to disastrous inundation should the right dike break. This danger is diminished by a secondary series of lateral embankments, placed at a considerable distance back of the dikes, along the whole course of the river below Cremona.

"The Po at this point is two hundred and eighty-five yards wide; has a swift, turbid current, and long sand bars are seen from the top of the dikes in the wide stretches, showing that in flood time a large quantity of sediment too heavy to be carried in suspension is swept along."

To a disinterested reader this description conveys the idea that the elevation of the surface of the Po has been a very appreciable quantity during the last half century, and that the bar-building forces have not been idle even in a stream of such paltry dimensions as compared with the mighty Mississippi.

L. F. Vernon-Harcourt says that—

"Numerous breaches have occurred in the embankments of the Po, resulting in the devastation of its valley; and the flood level of the Po has been so much raised that it has been decided not to heighten the embankments, for fear of occasioning still greater disasters. . . . . Some of the embanked rivers in Japan have their beds as much as 40 feet above the level of the plains above which they flow. . . . . They serve as a warning against the extensive raising of embankments to counteract the silting up of a river" (*Enc. Brit., River Eng.*, p. 588).

In his argument against bed elevation the same United States Engineer officer quotes a portion of a letter from another officer as to the condition of the Hoang Ho, who stated that he had crossed the Yellow river and visited the site of the great break, measuring the levees at various points, but that he had no instruments other than a hand-level and tape. "But," he says, "the conclusion I came to in regard to the influence of the levees upon the bed of the river was that they had nowhere filled it to a higher level than the adjacent country. . . . . I cannot but believe that Abbé Huc was entirely mistaken in regard to the silting up of the channel, and that an exhaustive survey would prove beyond doubt that no such silting as to raise any part of the bed above the adjacent country has ever taken place."

It seems almost superfluous to call attention to the indirect admission that the bed has risen, but not so much as to reach to or above the surrounding country, but it does not state that the flood height

does not reach above this danger line, as the disastrous breaks in late years attest fully. Moreover, no soundings were made and there was no basis for comparison.

But perhaps the most pronounced instance of bed elevation, due to a partial contraction along the banks of a stream near its outlet, and of which there can be no question, is that at the South Pass, where the constant and accurate surveys made since the construction of the two parallel jetties, in 1869, show they have produced an average shoaling along nearly the entire twelve miles of four inches and over per annum.

A recent Southern writer, evidently alive to the situation, stated: "The living generations will have great responsibilities in their treatment of this stalwart river, for it will not do to say that if the practice of building dikes proves ineffectual the true remedy may be applied at a later date. We know absolutely that the practice will prove ineffectual. This much we have already demonstrated in our own experience, even had we not the experience of twenty centuries to aid us in reaching conclusions; and every foot added to the elevation of the Mississippi river will be a measure of peril and perplexity for future generations. The time to apply the remedy is before the mischief is done." . . . . There should be no more Congressional appropriations for dike building, but the whole country can very properly be asked to help in providing for the security of future generations.

In the recent discussion before the American Society of Civil Engineers, it was stated that "the levees of the Po formed an immense network of dikes, which has assured the protection of a vast rich territory century after century." Also that "while the combined discharge of all the affluents amounts to 528,000 cubic feet per second, the discharge of the Po during the same period is only 176,000 cubic feet." The writer adds: "That is certainly a remarkable result, and doubtless much of it must be attributed to the fact that the tributaries do not discharge flood waters simultaneously and that the lakes retard the flow to a marked extent." . . . . He also adds: "There are, however, very serious drawbacks to levees as a means of preventing inundation, and Belgrand has stated that 'it is plain that even in a country where levees have existed for twelve centuries, where property has been exposed to all the consequences, it has not been clearly demonstrated that the advantages are greater than the inconveniences.' The chief objec-

tions are: (1) That they raise the flood heights; (2) that they break too easily and often; (3) that they cost too much; (4) that they cause the river bed to rise, because they do not permit the escape of sediment over the banks."

Moreover, it is important to note that the physical conditions attendant upon the drainage basin of the Po are wholly distinct from those of the Mississippi, since the Alpine tributaries with their steep decline of over a mile in twenty are checked and regulated by the magnificent and extensive storage and sedimentary basins of Lakes Maggiore, Como, Iseo and Gorda, from which the effluent issues comparatively clear and flows 340 miles to the sea, which is about 1260 feet below. The total basin drained by the Po covers but 27,000 square miles, while its mean discharge at the mouth is only 60,745 cubic feet, or about one-eleventh that of the Mississippi.

The benefit of the lakes as sediment basins is in part neutralized by the formation of pools in the bed of the stream, for the levees do not hug the banks closely but are in places miles apart, and they have been "so spaced at and near the mouths of important tributaries that the major bed forms a sort of reservoir, in which is stored not only the floods but still—and to disappear with time—the deposits carried by the affluents."

This disappearance takes place by the receding stage distributing the bars along the bed of the stream, thus causing elevation, as in the Mississippi, where similar pools are found to exist; so that, notwithstanding the great reservoirs on the tributaries of the Po, the defective alignment of the levees has aggravated the shoaling and bed elevation, as shown by the record.

But aside from general observations, the greatest weight should be given to the carefully conducted surveys made by the Mississippi River Commission, covering a reach of two hundred miles from the mouth of the Arkansas river to Vicksburg, and made at an interval of about twelve years, for the purpose of determining this question. The composite cross-sections of this reach show a fouling of the low-water channel to the extent of about four feet, and an enlargement of the area between low and high water amounting to nearly 17,000 square feet, due to the increased caving of the banks from the efforts of the augmented volume to enlarge its bed. This amounts to not less than 206,200,000 cubic yards of eroded material per annum in the reach of seven hundred and fifty miles from

Cairo to the Red river, from whence to the Gulf the volume is divided and the channel relatively permanent and deep. Here, even with a much flatter slope, the river is narrower and much deeper than necessary for the largest vessels, reaching in places two hundred feet and over, and yet it has been seriously proposed by the opponents of outlets to close the entrance into the Achafalaya, for fear lest that steeper and shorter route might ultimately become the main river and "New Orleans be left high and dry." As the city is on a waterway only a few feet above Gulf level, having ample depth except over the bars in the Gulf, there could be no possibility of such a calamity unless the stream were dammed at both extremities and the water pumped out. In fact it is on an arm of the Gulf, and if all the sediment were diverted through another channel it would greatly simplify the opening of the bars at the delta and improve the maritime conditions of the Port of New Orleans, which would soon be without a rival in this country. But, on the other hand, if the escape into the Achafalaya outlet were closed, the next flood would sweep away the city and all its inhabitants. This is the *reductio ad absurdum* to which the opposition to opening the outlets tends.

In short, the weight of the evidence points most emphatically to the conclusion that the building of levees materially increases the rate of shoaling in the bed of the river and the evils resulting therefrom.

From the foregoing citations it is reasonable to conclude that the effect of the levee system, *per se*, upon the navigable channel is at least negative, and hence the Commission has at length been forced to resort to the use of powerful hydraulic dredges for the purpose of temporarily increasing the depths across the bars during the season of low water. But so unstable are these cuts that in some instances they are redredged from three to four times within a few months during the low-water season, and the plant is of little use during the remainder of the year.

Moreover, under the Act of 1891, there would seem to be no authority for Federal appropriations for the levees, unless they are found "to afford ease and safety to the navigation and commerce of the river and to deepen the channel." It would also appear that the transient dredging of the bars does not fall within the requirements of creating a permanent channel, nor does it operate to "prevent destructive floods."

But "self-preservation is the first law of nature," and the local

belief in the efficacy of embankments for "the purpose of reclaiming lands or preventing injury to lands or private property from overflowing" is so innate that the occupants of such tracts are almost a unit in their demands for national aid for protection, and not without reason since they have a right to be protected in their lives, homes and property from the ravages of a common enemy from without. Since, under existing conditions, there appears to be no warrant for the application of the funds to reclamation works pure and simple, the law should be amended and an appropriation should be made directly for this purpose, independently of the commercial or navigation requirements. The lands thus reclaimed are among the most fertile and desirable within the Federal domain, and would become the source of a large volume of staple commodities for manufactures and food products. There is quite as strong an argument for the development of this portion of our territory by the exclusion of floods and their devastations, at the expense of the general Government, as there is for the fertilization of the arid lands of the Western plains by the application of irrigation. While one section has too much water at certain seasons the other has too little, and it is unquestionably the function of a paternal Government to equalize and regulate the distribution of this life-giving element for the general welfare.

To this extent and for this purpose levees are unquestionably useful, yet they are not the only resource of the engineering profession in alleviating floods and reclaiming lands. Drainage is an important factor, and this is based upon the principle of drawing down the water by gravity to lower levels and voiding it as rapidly as the topography will permit; but this important expedient has been vigorously opposed by levee advocates and set aside untried as purely theoretical, hence it is that attention is directed to a few physical facts as to the direct benefits to be derived from the opening of all possible avenues of escape of the flood waters, commonly known as the

Outlet System.

There has been much misunderstanding as to the practical application of this system, and erroneous impressions prevail as to its results in consequence of the deductions drawn from natural crevasses.

As the discharge from these openings returns to the main trunk

lower down through the tributaries, where the confluence of waters further obstructs the flow and causes deposits, it is claimed that outlets would be harmful. But this is not the condition which would prevail if properly constructed weirs and regulating works were placed so as to permit the discharge of a portion of the excess of the floods into suitably located impounding reservoirs, remote from the erosive action of the river currents. It is also claimed that the navigable channel would be injured by the reduction of volume below the crevasses and that the bed would rise in consequence thereof. This conclusion does not appear to be sustained either in theory or practice. On this point Generals Humphreys and Abbot state (page 387, *Physics and Hydraulics*), under the head of "Outlets": "This plan consists in reducing the flood discharge by waste-weirs and conveying the surplus water to the Gulf by channels other than that of the main river. The advantages of this system have been stoutly contested by many writers, on the ground that reducing the discharge of the Mississippi will occasion deposits in its channel, and eventually elevate rather than depress the surface of the river." In support of this opinion they have urged first that actual measurements upon the river at certain crevasses prove that deposits are made when the velocity is thus checked, and, second, that theoretical reasoning indicates that such deposits ought to be anticipated.

"Certain operations of this survey were conducted with especial reference to determine the effects of outlets, and they demonstrate, with a degree of certainty rarely to be attained in such investigations, that the opinions advanced by these writers are totally erroneous."

The report then analyzes the two cases cited in proof of the assertion, viz., the Fortier crevasse of April, 1849, and that of Bonnet-Carré of 1850, and shows that the phenomena attributed to the breaches were those ordinarily found to result from bends and straight reaches, and that in fact even in a natural crevasse there was no bar formed below such opening in the banks, and that "the assertions to the contrary are erroneous." They add: "There is no evidence whatever that any filling up of the bed ever did occur in consequence of a high-water outlet, and, moreover, it is impossible that it ever should occur, either from the deposition of sediment held in suspension or drifting along the bottom. The conclusion is then inevitable that, *so far as the river itself is concerned*,

they are of great utility. Few practical problems admit of so positive a solution."

Perhaps the best evidence on this much-mooted point will be found in the answer of Nature herself, so that an examination of the bed below the head of the distributaries will throw much light on the subject. Taking that portion of the delta below the Forts, which is in a state of nature and unleveed, it is observed that in the reverse curves swinging around these defenses, where the radii are but two and one and one-half miles, the greatest depths are thirty-one and twenty-nine fathoms respectively, due to the reaction of the sharp concave banks and the reduced width. As the radius lengthens to five miles the thalweg depths shoal to thirteen, twelve and eleven fathoms, and the river also widens gradually to the crevasse known as "The Jump," where the width exceeds a half mile and the depths increase to fifteen fathoms abreast of the opening, and to thirty-nine fathoms and "no bottom" at a quarter of a mile *lower down*, with over fifteen fathoms for several miles.

In this instance, therefore, the depth below the crevasse, instead of being less, is more than twice as great, and it is not due to local curvature but apparently to impact, due to the suction or set of the currents toward the right bank.

Continuing down stream as it widens out to a mile in breadth, the bed shoals to about six fathoms at the head of the Passes, which may be regarded as three crevasses, and yet it will be found that in each one of these distributaries the depths exceed those of the undivided stream. In the Pass à l'Outre it is twelve, in South Pass fifteen, and in Southwest Pass thirteen fathoms, with "no bottom," all at the points of incidence of the divided currents. Again in the Pass à l'Outre at the crevasse which formed in 1891, the depth abreast the opening is thirteen fathoms, and one mile below it is fourteen and one-half. This same stream again divides into two main branches, showing eight and one-quarter fathoms below the point of separation in the more direct channel, and eleven and one-half along the sharper concavity of the Southeast Pass, due to reaction of the bank. Without further elaboration, the same general results may be seen wherever a crevasse occurs, and there is no indication of shoaling due to the escape of the excess of the flood waters or loss of volume. On the other hand there is a very marked benefit observable in the relief afforded to the stream, for these openings enable it to discharge a large portion of its sediment beyond the banks

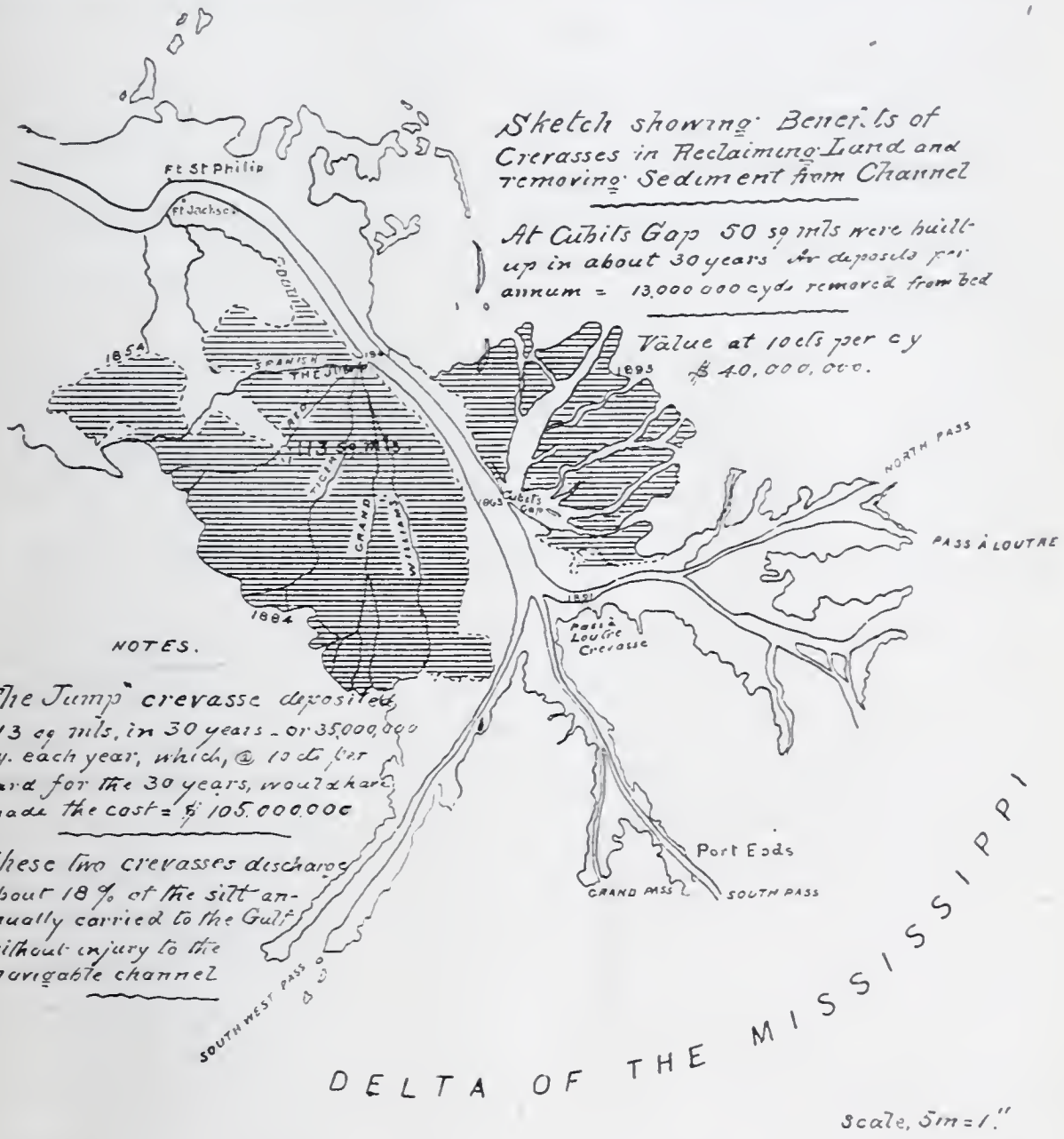
and out of the highway of commerce, which must otherwise be carried to the Gulf and be dropped directly across the channel, thus extending the trough, reducing the slope and increasing the height of the floods. In fact a former Chief Engineer of the State of Louisiana stated that the reason for selecting the Southwest Pass for improvement was because of its greater general depth, so that the shoaling which must result from the extension of the channel four miles by the two jetties would not so soon affect the navigable depths, in consequence of the contraction of the outlet.

As already stated, similar results have taken place in the South Pass above the jetties, where the fill in one place has exceeded forty feet. But these lateral outlets also play an important part in the reclamation of land, as well as in reducing floods and improving navigation, for by this method of hydraulic grading, without cost, large areas are gradually filled and converted into valuable plantations. The extent of these deposits may be roughly determined by a comparison of the United States Coast Survey charts of 1854 and 1884, from which it appears that the accretion to the land above water in the vicinity of the Bayou Grand Liard, Spanish Pass, Red Pass, Tiger Pass, Grand and William's Passes during the thirty years between the surveys amounted to about 113 square miles, or nearly 75,000 acres. At Cubit's Gap, where the river is straight and wide, the rate of deposit has also been considerable. This breach occurred in 1863, and within a few years an area of about eight square miles was raised above water; while a survey made by a Mr. Chucas Lewis in 1892 showed further deposits covering some forty-two square miles, which is already laid out (on paper), under the Government land system, into townships and sections.

A better idea of the extent of this contribution to the wealth of the nation may be obtained by computing the cost of securing it by the usual method of back-filling by the use of hydraulic dredging at, say, ten cents per cubic yard, and assuming the average depth to be nine feet. On this basis the total fill would aggregate some 400,000,000 cubic yards in the thirty years, or over 13,000,000 cubic yards per year. The total cost of securing this result by dredging, regardless of time, would therefore represent $40,000,000 for this one crevasse.

At "The Jump," where 113 square miles were reclaimed in about thirty years, the cost would have been $3,530,000 per annum if attempted by mechanical dredging, or $105,000,000 for the entire

time (or over $1,500 per acre), so that the cost would have been prohibitory. This one deposit, withdrawn from the river, averaged about 35,000,000 cubic yards annually; and as the total amount of sediment carried to the Gulf has been estimated by Humphreys and Abbot at 275,000,000 yards, it represents thirteen per cent. of the whole, while the annual deposit at Cubit's Gap is five per cent.,


Sketch showing Benefits of Crevasses in Reclaiming Land and removing Sediment from Channel
At Cubits Gap 50 sq mls were built-up in about 30 years Av deposits per annum = 13,000,000 cyds removed from bed
Value at 10cts per c y $ 40,000,000.
Ft St Philip
Ft Jackson
1854
SPANISH
THE JUMP
1894
113 sq mls
1884
1893
1863
Cubit's Gap
NORTH PASS
PASS À LOUTRE
1891
Pass à Loutre Crevasse
Port Eads
GRAND PASS
SOUTH PASS
SOUTH WEST PASS
NOTES.
The Jump crevasse deposited 113 sq mls. in 30 years - or 35,000,000 cy. each year, which, @ 10 cts per yard for the 30 years, would have made the cost = $ 105,000,000
These two crevasses discharge about 18% of the silt annually carried to the Gulf without injury to the navigable channel
DELTA OF THE MISSISSIPPI
Scale, 5m = 1."

making about one-sixth of the sediment which is thus withdrawn by these crevasses, with consequent benefit to navigation, reduction of flood height and increase of the public domain, all without cost.[1]

It would therefore seem that these *lateral outlets* have very much

[1] The depth of three yards was obtained by taking the average of a number of soundings covering the areas filled up by the crevasses (8.7 ft.).

to commend them to the consideration not only of engineers but of economists, business men, farmers and real estate dealers; and that, so far as the evidence of nature goes, their operation is only beneficial and in no wise injurious. If they were closed and the river leveed, all of the advantages named would be destroyed and the sediment would be carried to the mouth, where it would extend the bars more rapidly, raise the flood plain and require elevation of the entire system of levees along the river banks.

But there is another class of outlets which may be considered in this connection, and that is the bars which obstruct the mouths and thus prevent the free discharge of the fluvial waters. These may be distinguished as *longitudinal outlets*, and their permanent removal is entirely practicable by applying the energy of the river to the work to be done.

It is a well known fact that a sedimentary stream, flowing through a straight reach, seldom maintains a single permanent channel, while in swinging around curves the concave bank, acting as the directrix, causes a reaction which deepens the bed and deposits the silt upon the complementary convex bank which is the resultant of this action.

In this way, by the operation of natural laws, the deposits are removed from the path of navigation and the cross-section is automatically adjusted to the requirements of the river. Instead, therefore, of building two parallel jetties as substitutes for the natural banks, and thus extending the river into the Gulf at the expense of its slope and the reduction of its area of discharge along straight lines, which are unnatural and unfavorable, it will be found more rational to build one curved training wall so placed as to create a head and reaction which will transport the silt to the opposite or convex bank, where it will be deposited without cost, leaving an ample navigable channel and saving the expense of one of the jetties, while it also scours away the bar directly in front of the mouth and affords an open passage for the effluent water.

By thus utilizing the tendency of water to flow in curved lines instead of straight ones half the cost of the jetty works may be saved and a better and more permanent channel be obtained, with a lowering of the flood heights of the river. This result is due to the form of the orifice, and it will be seen that when no such modification is applied the effluent stream is abruptly checked by the inertia of the Gulf water and the sediment thus deposited acts as a

buffer to divide and deflect the energy into lateral components, which are again subdivided indefinitely, as shown in the typical forms of the deposits at Cubit's Gap; whereas when supported and concentrated by the continuous reaction of a properly placed resisting medium, the activity of the currents thus generated will prevent deposits near the trace of the work and create a neutral zone or counterscarp at some distance therefrom, which will thus become the site for the dump. These features may be observed wherever there are obstacles placed in the path of a current. The best artificial illustration of the efficacy of this principle as applied to a tidal inlet with a feeble tide is to be found at Aransas Pass, Tex.

The lowering of the flood plain by the removal of the barriers to the longitudinal discharge is also well illustrated by the operations on the River Tyne in England, where the flood heights have been reduced from nine to three feet along the stream by the opening of the mouth and removal of the bars from the bed.

Regardless, therefore, of the interests of navigation, it would be of great benefit to the State and nation to open the mouths of all the Passes for drainage and reclamation purposes, and by the use of the proper form of tool this could be accomplished more effectively and at less cost than by the methods now in vogue at the mouths of sedimentary rivers.

In the foregoing analysis it has been the intention to lay particular stress upon the necessity of so regulating the movements of the sediment as to prevent its being deposited in the pathway of the stream, where it may operate to obstruct its flow, causing elevation of bed, banks, levees and greater risks and expense; for it is evident that so long as the commingled earth and water are confined to the channel with no avenues of escape, the deposits must engorge the bed and involve continuous danger and expense.

It would seem that the attention of the engineering profession has been focussed mainly upon the control of the water, apart from its sediment, and with secondary consideration to the evils resulting from failure to separate these two elements, which, it is believed, may be done to great advantage at a number of points *en route* where lands may be reclaimed by the natural process of hydraulic grading, and large tracts of the richest arable land be recovered in a comparatively short time at a cost which will be insignificant as compared with that required to grade and drain it by mechanical means.

It is therefore desired to direct particular attention to the necessity of providing suitable dumping sites for the mud carried seaward by the river in times of flood, where it may be deposited beyond the banks of the stream without injury, through or over suitable weirs, and be retained by impounding dikes in the low swampy regions to their advantage.

The question is similar in its general features and effects to that prevailing at the inlets along alluvial coasts, where it was the practice to attempt the removal of the bars by jetties in pairs, supplemented by dredging; but which method has not been able to meet fully the demands of modern vessels, so that recourse is now being had to the control of the heavier earthy materials which compose these obstructions, in such manner as to protect the channels from their encroachments and cause the single concave jetty to construct and maintain much greater depths than exist in a state of nature.